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Emission Inventory for Criteria Pollutants of a Thermal Power Plant

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Abstract

The emissions inventory is the basic requirement for modeling of air quality, environmental monitoring and impact assessment. For any air pollution control program emission inventory is a key component. Emission inventory should be developed for acquiring emission data of significant amount. Fulfillment of air emissions inventory for a power plant identifies the source of air pollution. The air pollutants released from the entire source are measured to estimate the emission rates and emission concentrations.

In the present study, we made an emission inventory for criteria pollutants of Suspended Particulate Materials (SPM), sulfur oxides (SO_x), nitrogen oxides (NO_x) and carbon monoxide (CO) from stationary sources of a thermal power plant. Fuel consumption and emission database was developed for Rayalaseema thermal power project (1050 MW). Emission factors are calculated for the pollutants. The project lies on latitude of 14°42'52"N and longitude of 78°27'29"E located at VV Reddy Nagar, Kadapa, Andhra Pradesh, India. The methods used for inventory presentation are Manufacturers' design specifications and direct measurement. Results are compared from two methods.

Keywords: Thermal power plant; Emission inventory; Criteria pollutants; Modeling; Impact assessment

Introduction

Emissions inventory

The emissions inventory [1] is the primary task to identify the various sources of pollution from the particular project. It will give the physical and geographical conditions of the source. More reliable data can be produced regarding emission rates and emission concentrations. Systematic procedure is provided for emission inventory as follows:

Source identification

For the development of emission inventory [2] clear understanding of the project is essential. Physical site visit of the project and complete study on processing is essential to locate the required air pollution sources. Detailed review of maps or engineering drawings of the project site is essential; this can be obtained from review of literature on the industry. The sources of air pollution at the project identified the following:

- Release Type
- Location
- Emission of criteria air pollutants

Release type

Point sources, five stacks are identified with 220 m. tall and 4 m. diameter at the exit. These stacks emit flue gases into the atmosphere forcefully above ground level [3]. These are considered as tall point sources [2].

Wake: Affected Point Sources

There are no nearby buildings or other structures to interfere with the plume rise and dispersion. The point source is absolutely wake free source.

Location

The site of Rayalaseema Thermal Power Project [4] at Kalamala is located at a distance of 15 Km from Yerraguntla, 20 Km from Proddutur, 45 Km from Jammalamadugu and 8 Km from Muddanur railway station which is situated on Chennai-Guntakal Broad gauge line. The project site is at 180 m above MSL and is far away from any forest boundary. It lies on latitude of 14°42'52"N and longitude of 78°27'29"E. The project is located in an area of 1650 Hectares. The following Figure 1 depicts the location of the power plant where the study is carried out.

RTPP: Background

Andhra Pradesh state electricity board set up the Thermal power station at Kalamala with an installed capacity of 1050 Mw. It is established with five units under three stages. Each unit generates 210 mw of power. Table 1 gives the basic details regarding the capacity of the plant.

Criteria air pollutants emitted

Criteria air pollutants [5] from the source are: Suspended

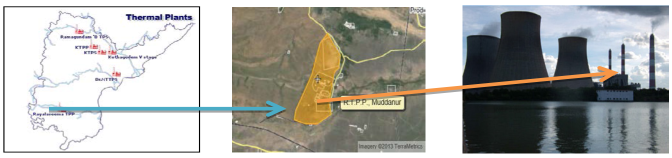

Figure 1: Rayalaseema TPP - Location map.

Stage / Stations	Units	Capacity (MW)	Date of Commissioning
Stage I	Unit 1	210	31-03-1994
Stage I	Unit 2	210	25-02-1995
Stage-II	Unit3	210	25-01-2007
Stage-II	Unit 4	210	20-11-2007
Stage III	Unit 5	210	29-11-2010
Total		**1050**	

Table 1: Installed capacity of power plant.

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Particulate Materials (SPM), sulfur oxides (SO_x), nitrogen oxides (NO_x) and carbon monoxide (CO) from stationary source of a thermal power plant. Ozone also produced as secondary pollutant from its precursors. All the pollutants produced are considered as photo toxicants [6]. They will show severe environmental impact on man, material, livestock and vegetation.

Methods for the Estimation of Emission Rates

There are number of methods [7] for the estimation of emission rate and emission concentration from each source. In the present investigation direct measurement, Manufacturer's design specifications and Emission factors [5] are used for emission inventory.

Manufacturer's design specifications

Manufacturer's design specifications are developed from composition of Singareni coal to estimate the emission rates of air pollutants from identified sources. Here quality of coal is taken into consideration to estimate emission rates and emission concentrations.

Fuel (Coal)

RTPP is linked with Singareni Collieries Co., Ltd., for supply of coal. This company has a proven coal resource of around 4000 million tones with 70% extractability. This company is sufficient to produce 30000 MW of electricity for 25 years. Annual coal requirements are calculated on the basis of the following and presented in Table 2.

Coal consumption 137 Tph. per unit

Coal consumption for 5 units = 137 × 5 = 685 Tph.

Coal consumption for 5 units = 685 × 24 × 365 = 6000600 Tones

Parameter	Mean Level
Hydrogen	2.74 %
Carbon	37.73 %
Nitrogen	0.74 %
Sulfur	0.44 %
Ash	44.84 %
Moisture	6.17 %
Oxygen	7.34 %
Gross calorific value	3686 K Cal/Kg

Table 2: Typical Ultimate Coal Analysis.

Combustion Product	Total Emission Rate
SO_2	3973 kg/h
NO_X	254.1 kg/h
H_2O	9.232 %
O_2	3.837 %
GCV	3698

Table 3: Calculated combustion products.

Coal combustion calculation results

The following Table 3 shows the results obtained from coal combustion calculated for the 685 Tons of coal per hour.

Direct measurement

In Rayalaseema thermal power project Emission rates and source release parameters are established from the results of source emission online flue gas monitoring system direct pc based automation system for monitoring & recording facility capable of monitoring O_2, CO, SO_2, NO_x, CO_2 gas, stack temperature, excess air, combustion efficiency system provided with all the required accessories as required install after economizer and near id fan, to make the fully functional.

Automatic flue gas sampling & filtration system, mounted in weather proof ip55 protected enclosure

SPM is estimated by gravimetric method.

Pollutant emission rates are directly measured from the stack by using continuous monitoring system [8]. All the parameters required for the presentation of emission inventory are measured directly at the source. This method is more appropriate and reliable in emission inventory [9]. Direct measurement includes all stack release parameters specified in Table 4.

Calculation of flue gas concentration for point sources

The equation used for the calculation of pollutant concentration released from a source is:

$$Cp = \frac{ERp}{FR} \qquad ....1$$

Where:

C_p = the concentration of pollutant p emitted in mg/m^3

ERp = the rate of emission of pollutant p in mg/s

FR = the flow rate of flue gas in m^3/s

The emission inventory can be expressed in two types of emission concentrations:

1. Actual concentration [10] of a pollutant released from a source in mg/Am^3. It is calculated from the measured gaseous volumetric flow rate (Am^3/s) and measured emission rate (Table 5).
2. Actual pollutant concentration released from a source is corrected to the normal conditions in mg/Nm^3 [10]. This is calculated using the gaseous volumetric flow rate corrected to normal conditions (dry, 273K, 101.3 KPa) (Table 5).

Total emission rates and concentrations from all stacks in Rayalaseema thermal power plant is presented in Table 6.

Emission Factors

An emission factor [5] is a value derived to calculate the emission of a pollutant throughout the process. These factors will give average

Source	Source type	Height of the Stack (m)	Exit Temperature of Flue gas (°C)	Diameter of the stack (m)	Exit Velocity (m/S)	O_2 (%)	H_2O (%)	Flow rate (Am³/S)	Flow rate (Nm³/S)
Stack - 1	Wake-free point source	220	140	4	28.1	4.5	9	3.37	**330**
Stack - 2	Wake-free point source	220	140	4	28.52	4.6	10	3.41	**328**
Stack - 3	Wake-free point source	220	140	4	29.9	4.2	9.3	3.46	**326**
Stack - 4	Wake-free point source	220	140	4	28.3	4.4	9.8	3.35	**324**
Stack - 5	Wake-free point source	220	140	4	28.7	4.4	9.6	3.37	**329**

Table 4: Stack source release parameters.

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Source	Pollutant	Emission Rate (gm./s)	Corrected Concentration (mg/Nm^3)	Regulated Concentration (mg/Nm^3 at stack reference conditions)
Stack -1	SPM	32.67	99	150
	Sulfur dioxide	224	679	NA
	Nitrogen oxides	13.53	41	NA
	Carbon monoxide	0.73	2.22	NA
Stack -2	SPM	32.8	100	150
	Sulfur dioxide	221.7	676	NA
	Nitrogen oxides	14.4	44	NA
	Carbon monoxide	0.73	2.24	NA
Stack -3	SPM	32.6	100	150
	Sulfur dioxide	221.6	680	NA
	Nitrogen oxides	14.67	45	NA
	Carbon monoxide	0.74	2.29	NA
Stack -4	SPM	33	102	150
	Sulfur dioxide	220.9	682	NA
	Nitrogen oxides	13.6	42	NA
	Carbon monoxide	0.71	2.2	NA
Stack -5	SPM	33.2	101	150
	Sulfur dioxide	206.2	679	NA
	Nitrogen oxides	13.1	40	NA
	Carbon monoxide	0.75	2.3	NA

Table 5: Stack Emission Concentrations.

Source	Pollutant	Total Emission Rate (kg/h)	Emission Concentration (kg/Nm^3 at stack reference conditions)
Stacks - 1,2,3,4 and 5	SPM	591.31	0.502
	SO_2	3939.84	3.396
	NO_X	249.48	0.212
	CO	13.176	0.011

Table 6: Total emission rates and concentrations.

Emission product	Emission Rate (Manufacturers' design specifications)	Emission Rate (Direct measurement)
SPM	----	591.31 kg/h
SO_2	3973 kg/h	3939.84 kg/h
NO_X	254.1 kg/h	249.48 kg/h
CO	----	13.176 kg/h
H_2O	9.232%	9.54%
O_2	3.837 %	4.42%
GCV	3698	3686

Table 7: Comparison of emission rates.

value of available data of acceptable quality, and these are generally representing long-term averages of the source type. Emission factors are used when other information is not available. Emission factors for criteria pollutants of Rayalaseema Thermal Power Project are calculated [11] as follows:

Emission Factor (EF) for SPM = ER/Activity …..2 (Emission control 99.5%)

591.31/685 = 0.863

Annual emission rate (ER annual) = EF × Activity annual ……3

Annual emission rate (ER annual) = 0.863 × 6000600 = 5178 Tpy

Emission Factor (EF) for SO_2 = ER/Activity …..4

3939.84/685 = 5.75

Annual emission rate (ER annual) = 5.75 × 6000600 = 34503 Tpy

Emission Factor (EF) for NO_X = ER/Activity …..5

249.48/685 = 0.364

Annual emission rate (ER annual) = 0.364 × 6000600 = 2184 Tpy

Emission Factor (EF) for CO = ER/Activity …..6

13.176/685 = 0.019

Annual emission rate (ER annual) = 0.019 × 6000600 = 114 Tpy

The emission factors calculated can be used to quantify the emissions of various power plants using coal from Singareni Collieries Co., Ltd., depending on the activity.

Presentation of Emissions Inventory

Comparison of emission inventory by Manufacturers' design specifications and direct measurements calculation results of total emission rates [7] of various combustion products are represented in Table 7.

Conclusion

This study provided all basic information and data required for air pollution modeling, and clearly described the details of site specific conditions. Emission rates of criteria pollutants and other combustion products are presented from two methods, Manufacturers' design specifications and direct measurement. Direct measurement is more accurate methodology for the development of emission inventory for coal combustion thermal power plants.

In this emission inventory presentation the results observed from Manufacturers' design specifications and direct measurement are comparatively equal. Emission rates provided can be applied for environmental modeling and for environmental impact assessment criteria. Emission factors also calculated for criteria pollutants for future estimations, if emission data is not available for that particular power project. Annual emission rates are provided from emission factors and annual activity.

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